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Performance Analysis of Vertical Up-flow Constructed Wetlands for Secondary Treated Effluent

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Abstract

The use of constructed wetlands for wastewater treatment has been exercised since 1950's and still are being in use. The vertical flow constructed wetlands provide more oxygenated environment and significantly reduce the organic matter as well as microbial species from wastewater. In the present study vertical up-flow constructed wetlands were constructed and used as bio-filter to improve the water quality of secondary treated effluent. The reduction pattern is studied in this research and correlated with plant species and presence of plant. The plant species used in the constructed wetlands were *canna* and *phragmitis*. The fibrous rooting system of *canna* species causes the high aerobic conditions throughout the treatment bed which in turn facilitates higher removal in comparison to *phragmitis* planted wetland. Removal of nitrogenous compounds like ammonia-nitrogen, TKN and nitrate were observed better in *canna* planted wetlands than others.

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Keywords: Constructed Wetland, *Canna Indica*, *Phragmitis australis,* Secondary treated wastewater

1. Introduction

In India, the availability of large land area is prime constraint for establishment of field scale constructed wetlands. While the subsurface vertical flow systems generally associated with about a 100 times smaller size range and 3 times smaller HRTs than the surface flow. Therefore, the vertical flow constructed seem to have an implication for better acceptability under Indian conditions [1], as it has been proven effective to treat

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different kind of wastewater worldwide including India. Till now presence of plants and their role for treatment of different type of wastewater is clear [2, 3], which increases the surface area for growth of microbes, which develops bio-film and transport oxygen upto 90 % within the system [4]. There is lack of rigorous comparative assessment of efficacy of constructed wetlands, planted with different plant species while using for tertiary treatment. Although the use of *phragmitis* and *typha* species for wetland establishment is a tradition since 1950's and still going on. *Canna indica* is commonly used plant for wetland establishment in China and other countries [5, 6] as it has rapid growth rate, large biomass and beautiful flowers with great capability of nutrient removal [7]. *Canna indica* is known as phytoremidation plant [8], had a flourishing root system with higher root growth, higher root number, larger root biomass and significantly larger root surface area than the other plant species. This plant has great tolerance to the pollutants and has long root life span [9]. To our knowledge limited information is available for use of vertical up-flow constructed wetlands for post treatment technology. The present research aim the suitability of *canna india* for post treatment over the use of unvegetated and vegetated with *phragmitis* constructed wetland by flowing the up-flow of wastewater in favour of aesthetic appearance.

2. Material and method

Four up-flow constructed wetlands were constructed at Malaviya National Institute of Technology, Jaipur, India. Secondary treated wastewater was taken from the STP which is based on Activated Sludge Process and applied to all the wetland units. The wastewater was kept in the feeding tank and allows passing water through ports, peristaltic pump and valves to all wetland units separately. Water flows upward through the treatment bed and reaches the surface and finally the treated effluent passes out from the top most port and gets collected in the effluent collector placed underneath it. The water-flow in each of the bed is controlled using peristaltic pump and collected in inlet chamber in all units which allows uniform distribution throughout the bed. The percent removal efficiency of contaminants has been analyzed according to [10] by using inlet and outlet samples on weekly basis. Vegetation and media characteristics for each treatment unit are given as below in table1. Size and distribution of gravel in all units were same as 8-12mm gravel were placed at the top and 16-20mm gravel at the bottom.

Table 1. Different constructed wetland units with different plantation as well as media type

UFCW	Vegetation	medium
Unit1	phragmitis	gravels
Unit2	canna	gravels
Unit3	none	gravels
Unit4	canna	gravels with sand

Analysis is based on inlet and outlet sampling. A total of 20 water samples were collected on weekly basis for constructed wetland units which are planted with *canna* (with and without sand layer incorporation). The inlet samples were collected at the port located at the base of the each unit and the outflow samples were taken from the port located at the distal end. Samples were collected in autoclaved 100ml beakers and were sealed with aluminum foil. The samples were immediately transferred to the Environmental Engineering laboratory of Civil Department at MNIT Campus and analyzed within 12hrs for physicochemical analysis.

3. Result and discussion

The constructed wetlands proved efficient to reducing the many physical and chemical contaminants associated with secondary treated wastewater. The influent and effluent concentration for all constructed wetland units are shown in fig1. pH values ranges from 8.19 to 8.38 in influent and effluents of all the units. In the present research tertiary treatment is targeted and organic matter removal efficiency was evaluated in

terms of COD removal and nutrient analysis has been made by analyzing ammonia-nitrogen, TKN, nitrate concentrations.

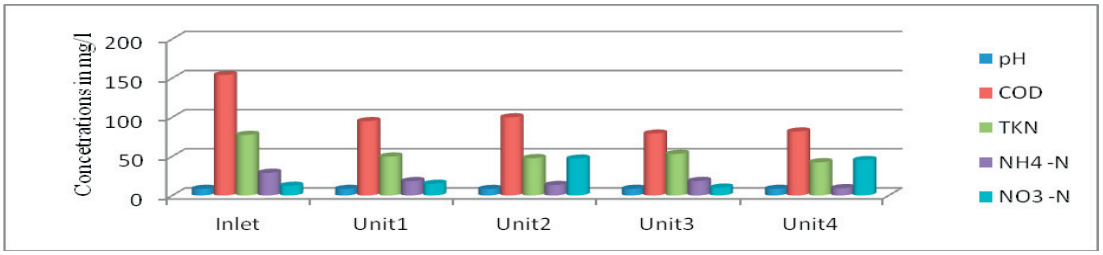

Fig. 1. Mean concentrations of influent and effluent of all four treatment units. All mean concentration are shown in mg/l (n=20).

3.1. Removal of COD

Mean influent concentration of COD was 159.95 mg/l and the effluent concentration of all treatment units was in the limits of prescribed standard by WHO i.e. 120-150mg/l: ranges from 81.64 to 99.8 mg/ depending upon presence of different constituents in different units. The mean percentage COD removal for uni1 unit2 unit3 and unit4 was 38.39%, 35.17%, 48.70% and 46.97% respectively. This indicates that sedimentation and filtration played important role in control unit which is responsible for higher COD removal than biodegradability [11, 12]. The increased removal in control units may also be facilitated due to sequential presence of anaerobic and aerobic conditions in Up-flow constructed wetlands where both mechanisms were in contribution for removal of organic matter as denitrifiction and aerobic biodegradation were played major role for excellent COD removal in control unit [13, 14]. Also an author [15] gives apparent reason for COD removal due to combine effect of aerobic and anaerobic organic carbon degradation. As it is known that the uptake of organic matter by plants is of less significant [16] the organic matter removal is not dependent on the presence/ absence of plant species in constructed wetlands.

Percentage removals are in accordance with [17, 18], where COD removal was ranges from 38 to 47% while treating domestic wastewater through vertical flow system. The author [19] also observed lower COD removal in one case of non-planted wetland than planted one. This is contradictory observation to other reported studies [20, 17] where the higher organic matter removal is achieved in planted wetlands as the plants increases the surface area which increases growth of bio-film within the treatment beds [2]. Till date the significance of plant presence is remains contradictory to state.

3.2. Removal of NH4-nitrogen, NO3-nitrogen and TKN

However the effect of different operational factors on nitrogen removal may indeed be different from that of the removal of COD. Removal of ammonia-nitrogen in planted and unplanted system was 52.99% and 36.17% respectively which greatly supports the significance of presence of macrophytes. The well known phenomena about the presence of macrophytes for release of oxygen in the rhizosphere [21] resulting increased aerobicity within the treatment bed and uptake by plants played the key roles for the removal of ammonia-nitrogen in planted units. The % removal efficiency of ammonia-nitrogen was observed higher in unit 2 and unit4. Both the units were planted with *canna indica*. It could be stated that the presence of *canna indica* greatly affects the removal of nutrients. The fibrous rooting system helps to prevailing aerobic conditions throughout the treatment bed. Especially in case of compact wetland, presence of *canna indica* could be of great significance. The high leaf area (value not calculated) might help to increase the assimilation process and lead to incorporate in higher removal of nutrients. The increased removal of amonical nitrogen

from *canna indica* planted wetlands through subsurface up-flow constructed wetlands has been observed in study [22]. The increased concentration of nitrate in planted bed and removal of TKN by planted and unplanted wetlands were also in accordance with the obtained results which ensure that presence of plants is of great importance for removal of nitrogen.

These results are in good agreement than [17] where ammonia nitrogen is removed by 45.3 and 34.8% for planted and unplanted constructed wetlands respectively and [23] where nitrogen is removed by 49.37% through planted sand filter although for effluent of secondary treated wastewater followed by floating bed. The observed results of this research are in accordance as [14]. Overall removal found from all treatment beds could be reasoned: vegetation influences interaction between plants-wastewater—microorganism, provide microbial attachment sites, sufficient wastewater resident time, trapping and settlement for wastewater components, surface area for pollutants adsorption, uptake storage in plants diffusion of oxygen from rhizosphere [24].

3.3. Importance of presence of Canna plantation

In this study, it should be possible to evaluate the relative importance of presence of different plant species, with incorporation of sand based system for removal of nitrogenous matter. If comparison made between different units of different plantation: Removal of NH_4–N is in such order; unit4>unit2>unit1>~unit3. It indicates that the presence of *canna indica* may improve the aerobicity within the wetland bed in comparison to presence of *phragmitis australis*. The increased concentration of nitrate in unit4 and unit2 also confirms the presence of comparable aerobic conditions. The significant presence of *canna indica* for vertical flow constructed wetlands was also observed by [25] and [26] for removal of nutrient from primary and secondary treated wastewater. TKN removal was also observed in the same manner which also favors the use of *canna indica* than *phragmitis australis* for plantation in constructed wetlands. The overall improved removal of contaminants in *canna indica* planted wetlands (unit2 and unit4) can be defined by its fine- fibrous rooting system [27]. *Canna indica* have rapid growth rate and large biomass, which may increase the surface area for bio-film to grow and in turn increase the overall microbial activity by providing more oxygen release, especially the aerobic activity because fast growing plants with higher roots are favorable for nitrifying bacteria to enhance the nitrification [7, 24].

4. Conclusion

This could be inferred that among the three categories of pollutants such as organic matter, nutrients and microorganism (data not shown), wetland-establishment-suggestions could only be made by concerning the ultimate goal, as the wetlands perform different for each parameter in this research. Significant impacts of plantation were shown, especially for removal of nitrogenous compounds. The overall better performance was observed from *canna* planted wetland. The overall performance is in order: unit4>unit2>unit1≥unit3. As the *canna* has its aesthetic appearance, it could be suggested as a good option for plantation for development of wetlands which may lead its public acceptance too. So far, it could be suggested that the vertical up-flow constructed wetlands which is constituted with gravel with sand for media and plantation with *canna*, suitable for post treatment technology. Research is further continuing for the efficacy of these wetlands for removal of microbiological contaminants also.

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References

[1] Kaur R, Wani S. P, Singh A. K, Lal K. Wastewater production, treatment and use in India. *Country report India*; 2012.

[2] Brix, H. Do macrophytes play a role in constructed treatment wetlands? *Water sci. technol*. 1997; 35(5): 11–17.

[3] Stottmeister U, Wießner A, Kuschk P, Kappelmeyer U, Kästner M, Bederski O, Mullar R.A, Moormann H. Effects of plants and microorganisms in constructed wetlands for wastewater treatment. *Biotechnol. adv.* 2003; 22: 99–117.

[4] Reddy K. R, D'Angelo E. M, DeBus T. A. Oxygen Transport through Aquatic Macrophytes: The Role in Wastewater Treatment. *J. Environ. Qual*. 1989;19: 261-267.

[5] Cristina S.C, Calheiros, Anto´nio O. S. S. Rangel, Paula M.L. Castro. Constructed wetland systems vegetated with different plants applied to the treatment of tannery wastewater. *Water research.* 2007; 41: 1790 – 1798.

[6] Naz M, Uyanik S, Yesilnacar M. I., Sahinkaya E. Side-by-side comparison of horizontal subsurface flow and free water surface flow constructed wetlands and artificial neural network (ANN) modeling approach. *Ecological Engineering*. 2009; 35: 1255–1263.

[7] Liang M. Q, Zhang C. F, Peng C. L, Lai Z. L., Chen D. F, Chen Z. H. Plant growth, community structure, and nutrient removal in monoculture and mixed constructed wetlands. *Ecological Engineering* 2011; 37:309–316.

[8] Bose S, Jain A, Rai V, Ramanathan A. L. Chemical fractionation and translocation of heavy metals in *Canna indica* L. grown on industrial waste amended soil. *J. Hazard. Mater*. 2008; 160: 187–193.

[9] Wenyin C, Zhanghe C, Qifan H, Xiaoyan W, Cairong W, Defeng C, Zenglong L. Root growth of wetland plants with different root types. *Acta ecologica sinica.*2007; 27(2):450-458.

[10] Lenore S. C, Arnold E. G, Andrew E.A, ed. *Standard methods for the examination of water and wastewater*, 20th ed. US: American public health association (APHA); 1999.

[11] Aslama M. M, Malikb M, Baiga M. A, Qazia I. A, Iqbalc J. Treatment performances of compost-based and gravel-based vertical flow wetlands operated identically for refinery wastewater reatment in Pakistan. *Ecol. eng.* 2007; 30: 34–42.

[12] Koottatep T, Polpraserta C, Oanh N.T. K, Heinssb U, Montangero A, Strauss M. Potentials of vertical-flow constructed wetlands for septage treatment in tropical regions. *Advances in water and wastewater treatment technology*, 2001; 315-325.

[13] Vymazal, J. The use of sub-surface constructed wetlands for wastewater treatment in the Czech Republic: 10 years experience. *Ecol. eng*. 2002; 18: 633–646.

[14] Ong S. A, Uchiyama K, Inadama D, Yamagiwa K. Simultaneous removal of color, organic compounds and nutrients in azo dye-containing wastewater using up-flow constructed wetland. *Journal of hadardous material*. 2009; 165: 696-703.

[15] Zhang D. Q, Tan S. K, Rechard M. Zhu G. J, Sadreddini S, Li Y. Nutrient removal in tropical subsurface floe constructed wetlands under batch and continuous flow conditions. *Journal of environmental management*. 2012; 96:1-6.

[16] Watson J. T, Reed S. C, Kadlec R. H, Knight R. L, Whitehouse AE. Performance expectations and loading rates for constructed wetlands. In: Hammer DA (ed) Constructed wetlands for waste water treatment. *Lewis Publishers, Chelsea, MI*. 1989; 319–351.

[17] Gikas G. D, Tsihrintzis V. A. A small-size vertical flow constructed wetland for on-site treatment of household wastewater.*Ecol. Eng*. 2012; 44: 337– 343.

[18] KORKUSUZ E. A, BEKLIOGLU M, DEMIRER G. N. Treatment efficiencies of the vertical flow pilot-scale constructed wetlands for domestic wastewater treatment. *Turkish J. Eng. Env. Sci*. 2004; 28: 333 -344.

[19] Stefanakis A. I, Tsihrintzis V. A. Effects of loading, resting period, temperature, porous media, vegetation and aeration on performance of pilot-scale vertical flow constructed wetlands, *Chemical engineering journal*. 2012; 181– 182: 416– 430.

[20] Sirianuntapiboon S, Chandanasotthi T, Sohsalam P, Rarunroeng M, Sansak J. Application of para-wood charcoal as the media of the vertical-flow constructed wetland for treatment of domestic wastewater. *African journal of agricultural research* 2007; 2(4): 191-199.

[21] Bodelier P, Libochant A. J, Blom C, Laanbroek H. Dynamics of nitrification and denitrification in root-oxygenated sediments and adaptation of ammonia oxidizing bacteria to low-oxygen or anoxic habitats. *Appl. environ. microbiol*. 1996; 62: 4100–4107.

[22] Chang N. B, Xuan Z, Daranpob A, Wanielista M. A subsurface up-flow wetland system for removal of nutrients and pathogens in on-site sewage treatment and disposal systems. *Environmetal engineering science*, 2010; 00, 00.

[23] Xiong J, Guo G, Mahmood Q, Yue M. Nitrogen removal from secondary effluent by using integrated constructed wetland system. *Ecol. eng*. 2011; 37: 659–662.

[24] Kyambadde J, Kansiime F, Gumaelius L, Dalhammar G. A comparative study of *Cyperus papyrus* and *Miscanthidium violaceum*-based constructed wetlands for wastewater treatment in a tropical climate. *Water reserch*. 2004; 38: 475–485.

[25] Zhang Z, Rengel Z, Meney K. Nutrient removal from simulated wastewater using *Canna indica* and *Schoenoplectus validus* in mono- and mixed-culture in wetland microcosms. *Water Air Soil Pollut*. 2007b; 183: 95–105.

[26] Cui L, Ouyang Y, Lou Q, Yang F, Chen Y, Zhu W, Luo S. Removal of nutrients from wastewater with *canna indica* L. under different vertical flow constructed wetland conditions. *Ecological engineering*, 36, 2010, 1083-1088.

[27] Yang Q, Chen Z. H, Zhao J. G, Gu B. H. Contaminant removal of domestic wastewater by constructed wetlands: Effects of plant species. *J. Integr. Plant Biol.* 2007; **49**(4): 437−446.